SHOUT
SHARE
IT

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 796

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. October 21, 1919

USE OF TOXIC GASES AS A POSSIBLE MEANS OF CONTROL OF THE PEACH-TREE BORER.

By E. B. BLAKESLEE, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

CONTENTS.

	Page.		Page.
Introduction	1	Experimental results	3
Experimental procedure	2	Summary	22

INTRODUCTION.

The study of poisonous gases and their use as a possible means of control of the peach-tree borer, *Sanninoidea exitiosa* Say, of which the present paper is a brief report, was begun in 1915, under the direction of Dr. A. L. Quaintance, in charge of deciduous fruit insect investigations, of the Bureau of Entomology. In this investigation the attempt has been made to develop a method of control by the use of local applications of volatile toxic compounds in the soil at the base of the trees. On account of the intimate association of the insect and its host, any gas fully efficient as a larvicide must necessarily have more or less effect upon the tree. In this respect, however, the problem presents nothing unusual, as the application of insecticides generally and the fumigation of living plants especially is restricted to a greater or less extent by the same limitation. In the case of the peach-tree borer the insect and its host are by no means susceptible to fumigation in the same degree. Also, for various reasons, a much wider margin of safety to the tree is afforded by some gases than by others.

It has been necessary, in regard to fumigation, to take into consideration the manner in which it is affected by soil and atmospheric temperatures, soil type, soil moisture, rainfall, seasonal development of the insect and its host, and their relation to the chemical properties of the materials tested, such as the volatility and solubility of the gas, etc. In 1916 daily determinations of soil moisture and records of soil and atmospheric temperatures and rainfall were obtained in connection with each experiment, but on account of the

infinite variation of such factors under field conditions it has been found impossible to correlate these data with the results of the experiments except in a very general way. For the most part, therefore, conclusions have been based on the results of fairly extensive field tests with only a general analysis of the conditions involved.

A number of substances have been tested and many data accumulated which it is impossible to include in the present paper. In so far as promise of providing a safe and effective control measure for the insect is concerned, all of the gases tested have given negative results except one, p-dichlorobenzene. The results obtained from the use of this material are so promising that it has seemed best to report upon the present experimental status of the work for the information of others interested in the problem. Also it is hoped that as far as possible useless duplication of work with some of the other less promising gases may be prevented.

EXPERIMENTAL PROCEDURE.

As already stated, the essential idea of the experiments involves application of volatile toxic compounds to the soil at the base of the trees. In one experiment small tents were used to confine the gas, but this method, on account of the mechanical difficulties involved, was never used to any great extent. The soil under all ordinary conditions proved a fairly satisfactory container for the gas. Whether the material was applied in water solution or in its original form depended upon its chemical properties. Whenever possible both methods of application were adopted. When applied either in solution or suspended in water, a trench was dug about the collar of the tree as for "worming" and the required dose, in from 1 to 2 gallons of water, puddled about the trunk, after which the soil was replaced and compacted. When applied in its original state the material, if a liquid, was poured into the soil about the collar, and if a solid, was buried in the surface soil about the trunk.

Two methods of ascertaining results were followed. In the first the treated trees were examined within a short time after application, usually within a few days, the results being judged by the mortality of the larvæ. The interval from application to examination was usually varied sufficiently to determine the toxicity of the fumigation. In the second method the treatments were made either in late fall or early spring and examination made several weeks or several months later, before the infestation of the next season. By this time dead larvæ usually had largely decomposed, and it was necessary to judge the effectiveness of the fumigation by a comparison of the number of active larvæ escaping on the treated trees with the num-

ber active on untreated trees in adjoining rows. In all cases the effect of the fumigation on the tissues of the tree was carefully noted, the margin of safety being considered as fully as the larvicidal action of the gas. Injury to the trees has been classified under the following terms: Trace, slight, moderate, severe, and maximum. Maximum injury applies to cases where the tree has been girdled completely by the fumigation, and no doubt remains of its immediate death. Severe injury indicates that the tree has been girdled partially, sufficient to destroy permanently its productive value, but not to cause its immediate death. The other terms, moderate, slight, and trace, represent a gradually diminishing degree of injury, the last term indicating that the effect of the gas was only sufficient for identification. The first two terms, trace and slight, represent injury which is of little or no importance as far as the effect upon the tree is concerned.

EXPERIMENTAL RESULTS.

MISCELLANEOUS GASES.

The principal materials that have been tested are carbon disulphid, carbon tetrachlorid, hydrocyanic-acid gas, naphthalene, and para-dichlorobenzene. In the discussion of the relative merits of these materials the results are given in detail only for the last, p-dichlorobenzene.

Carbon Disulphid.

In 1902 Woodworth[1] recommended the use of carbon disulphid against the western species of peach borer. Under the proper condition of soil moisture and temperature it is a most efficient larvicide. In practice, however, it was found impossible to standardize its use to an extent which would make it both safe and effective. The main difficulty with this material arises from its great volatility at ordinary temperatures, which makes it very sensitive to variations in soil porosity. In very dry or porous soils, large doses of several ounces may be applied with no effect upon the larvæ. On the other hand, in very moist, tight soils, large vigorous 12-year old trees have been entirely girdled by an application of as small a dose as one-fourth of an ounce. Its application in water emulsion was found to standardize soil conditions greatly, and successful treatments by this method with greatly-reduced doses have been made on hundreds of trees without injury. A very slight misjudgment in dosage for a given set of conditions, however, gave results of an opposite character, and after two and one-half years' experience with this gas its use has been entirely abandoned.

[1] Woodworth, C. W. The California peach-tree borer. Cal. Agr. Exp. Sta. Bul. 143. 1902.

Carbon Tetrachlorid.

Carbon tetrachlorid does not differ essentially from carbon disulphid, in so far as its effect upon the tree or its larvicidal action is concerned. To achieve the same result it seemed to require about double the dosage of the disulphid. Its chief merit as a fumigant seems to lie in the fact that the vapor is not inflammable.

Naphthalene.

Naphthalene was tested quite fully in 1916 and 1917. For the greater part of the year it vaporized just fast enough to give the soil about the base of the tree a pronounced odor, but apparently produced no effect upon the insect or the tree. With a soil temperature of 70° F. and over, attained in July and August, there is a very decided larvicidal action, but not sufficient to make this material of value.

Hydrocyanic-acid Gas.

Hydrocyanic-acid gas, while a very effective larvicide, proved too dangerous. The great solubility of this gas effectually prevents the standardization of its use. Variation in moisture content and in the type of soil so greatly affect the absorption of this gas by the latter that it has been found impossible to establish any standard dosage that is both effective and safe for any number of conditions. Moist soils required much larger doses than dry soils or soils of low water-holding content. This point has been fully covered by Ong[1] in a recent publication. The great solubility of the gas, furthermore, leads to its rapid absorption by the portions of the tree with which it comes in contact, which probably explains in part the considerable injury resulting from its use.

PARA-DICHLOROBENZENE.

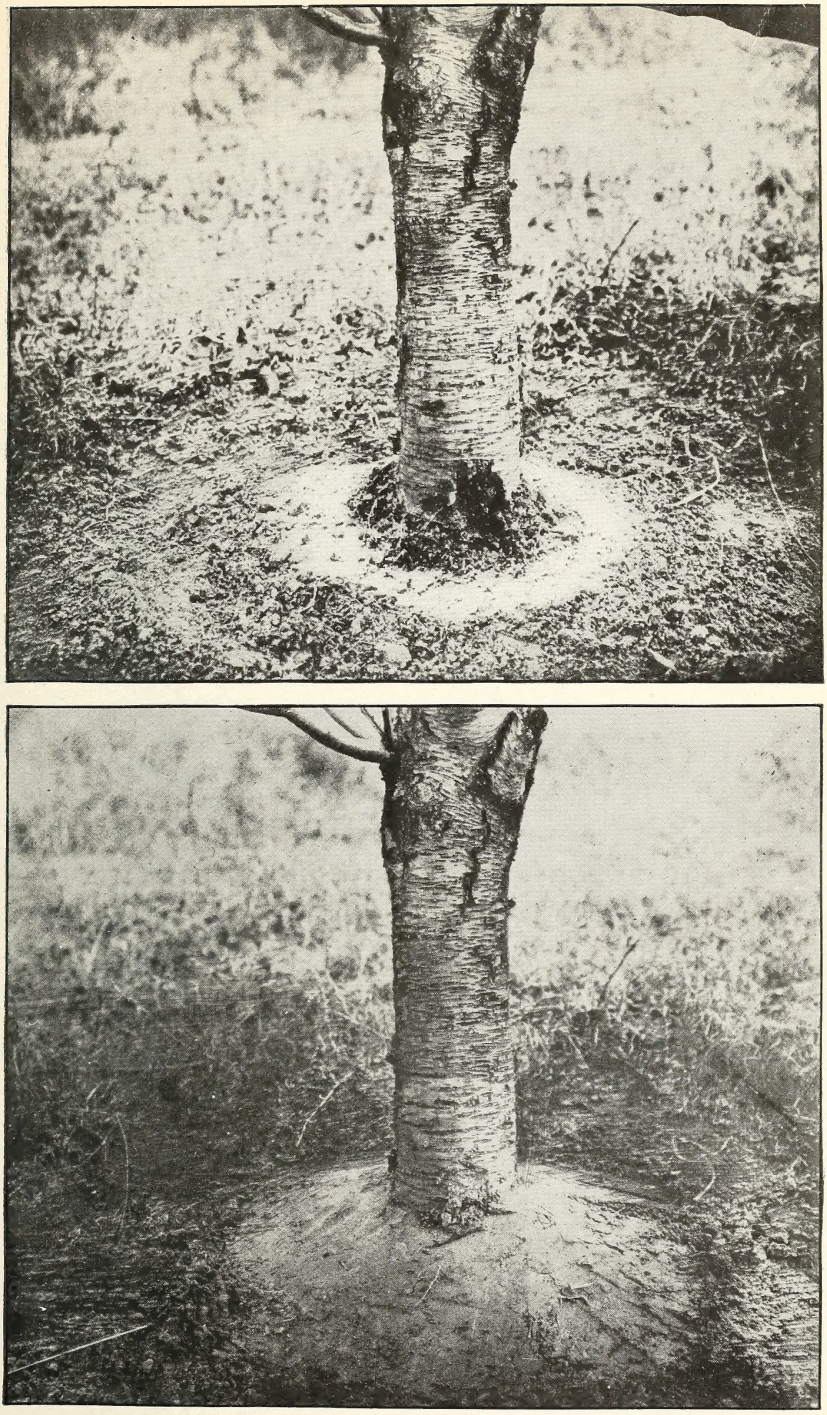
Insecticidal, Physical, and Chemical Properties.

Of the various volatile compounds tested, the merits of some of which have been briefly discussed, para-dichlorobenzene has been by far the most promising. While well known chemically, its value as an insecticide is of comparatively recent discovery.

Of the various volatile compounds tested, the merits of some of which have been briefly discussed, para-dichlorobenzene has been by far the most promising. While well known chemically, its value as an insecticide is of comparatively recent discovery. Duckett,[2] in 1915, published a report on the insecticidal value of its vapor as a fumigant against various insects. Later in the same year Cook,

[1] Ong, E. R. de. Hydrocyanic-acid gas as a soil fumigant. *In* Jour. Agr. Research, v. 11, no. 9, p. 421–436. 1917.

[2] Duckett, A. B. Para-dichlorobenzene as an insect fumigant. U. S. Dept. Agr. Bul. 167. 1915.



METHOD OF APPLYING PARA-DICHLOROBENZENE FOR CONTROL OF THE PEACH-TREE BORER.

Above: Tree with soil crust broken about the collar and one ounce of para-dichlorobenzene applied.
Below: Same tree with soil placed over the material and compacted.

Hutchison, and Scales[1] reported rather indifferent results from its use against fly larvæ in horse manure. Moore[2] used it in 1916 in the fumigation of animals to destroy their external parasites and found it less effective for that purpose than nitrobenzene. Its chemical formulæ and physical properties are discussed fully in Duckett's report. It is a crystalline solid at ordinary temperatures, insoluble in water, melting at 53° C., and boiling at 172° C. Like naphthalene it vaporizes much below its boiling point, although only very slowly at ordinary temperatures. Its vapor pressure and rate of volatilization are discussed on page 21. Apparently, however, when vaporization takes place in a closed container of a capacity appropriate to the dose, or under conditions approximate to that, the evolution of gas even at ordinary temperatures is sufficiently rapid to produce eventually an atmosphere of toxic saturation.

Method of Application.

The method of application for the use of p-dichlorobenzene against the peach borer is illustrated in Plate I. The mechanical condition of the material, on account of its relation to the rate of evaporation, is of considerable importance. The action of the gas is quite local and an even distribution about the tree is highly desirable. It was found that p-dichlorobenzene was most convenient and satisfactory for use when pulverized to about the fineness of coarse salt or granulated sugar. The form in which it usually appears on the market may be reduced to this condition by crushing and sifting through a 12-mesh screen. In this condition it does not lump badly, can be evenly distributed, and vaporizes at about the proper rate.

In making application the soil crust is first broken to a depth of 1 or 2 inches with a hoe, or some other suitable tool. The vapor of p-dichlorobenzene is about five times heavier than air and it is not desirable to apply it deeper than is necessary to avoid washing and surface loss of gas. The soil is not scraped away from the collar of the tree unless there is a decided mound. The material is placed as nearly as possible at the level of the uppermost galleries. The soil, moreover, should not be disturbed except to break up the surface crust. The gas will permeate very tight soils readily, and any unnecessary digging up of the soil about the collar only makes more air space to be saturated, and increases the chance of ineffective fumigation. After the preparation of the soil surface the p-dichlorobenzene is sprinkled as evenly as possible about the collar of the tree in a band 1 or 2 inches wide. In practice the material may be con-

[1] Cook, F. C., Hutchison, R. H., and Scales, F. M. Further experiments in the destruction of fly larvæ in horse manure. U. S. Dept. Agr. Bul. 245. 1915.

[2] Moore, Wm. Fumigation of animals to destroy their external parasites. *In* Jour. Econ. Ent., v. 9, no. 1, p. 71–78. 1916.

veniently carried in an open pail and the dose measured in a graduate holding just the desired amount. A little preliminary practice with the graduate and scales enables one to gauge the dosage very correctly. It is probably best to keep the material from actual contact with the bark by perhaps half an inch, although the practical importance of this precaution is not known. Finally, the material is covered to a depth of 2 inches with two or three shovelfuls of soil, and this slight mound compacted by a few sharp blows with the back of the shovel. The soil is the container for the gas, and the success of the fumigation depends upon the vapor being given off faster than it is lost. At best there is considerable surface loss of gas, and the final compacting of the soil is of considerable importance. No lumps or stones are left against the trunk above the surface to furnish a harbor behind which newly-hatched larvæ may begin feeding out of reach of the vapor. No effect, of course, can be produced upon larvæ feeding in galleries above ground.

Larvicidal Action.

To determine the actual larvicidal value of the vapor of p-dichlorobenzene, a series of applications were made to trees in the field at Springfield, W. Va., in 1916. The approximate limits of effective dosage had been fairly well established by preliminary experiments. Each dose was applied to 20 trees and these examined in lots of 5 at approximately weekly intervals.

Table I gives the summarized results of several such tests. It is impossible to include all of the experiments made in this connection, but the data given bring out the essential facts in regard to dosage efficiency. The soil on which these experiments were made is classified as Frankstown silt loam.[1]

[1] Determination of soil type furnished by the Soil Survey of the Bureau of Soils, United States Department of Agriculture.

TABLE I.—*Larvicidal action of stated doses of p-dichlorobenzene after specified periods of fumigation. Springfield, W. Va., 1916.*

Dose per tree.	Date of application.	Number of trees.	Date of examination.	Number of days from application to examination.	Number and condition of larvæ of specified maturity.														
					Dead.					Stupefied.					Active.				
					One-fourth grown.	One-half grown.	Three-fourths grown.	Full grown.	Total.	One-fourth grown.	One-half grown.	Three-fourths grown.	Full grown.	Total.	One-fourth grown.	One-half grown.	Three-fourths grown.	Full grown.	Total.
One ounce	July 19	5	July 28	9	6	18	6	2	32	1	4	1	.....	6	.....	.....	.....	.....	.....
		5	Aug. 2	14	2	16	8	3	29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		5	Aug. 9	21	2	11	17	10	40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		4	Aug. 21	33	.....	6	5	3	14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Aug. 17	5	Aug. 24	7	21	1	1	1	24	.....	5	.....	.....	5	1	.....	.....	.....	1
		5	Aug. 31	14	21	7	1	1	30	1	2	1	.....	4	5	2	.....	.....	7
		5	Sept. 11	25	13	3	.....	.....	16	1	2	.....	.....	3	.....	.....	.....	.....	.....
		5	Sept. 25	39	.....	.....	1	1	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
One-half ounce	July 19	5	July 27	8	1	5	3	1	10	2	3	.....	.....	5	.....	.....	.....	.....	.....
		5	Aug. 2	14	1	3	5	2	11	1	.....	.....	.....	1	.....	.....	.....	.....	.....
		5	Aug. 9	21	1	5	9	2	17	.....	.....	.....	.....	.....	.....	1	.....	.....	1
		5	Aug. 21	33	2	6	3	4	15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Aug. 17	5	Aug. 24	7	6	1	.....	.....	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		5	Aug. 31	14	10	4	.....	.....	14	2	2	.....	.....	4	.....	.....	.....	.....	.....
		5	Sept. 11	25	1	2	2	.....	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		5	Sept. 25	39	1	1	.....	.....	2	2	2	1	.....	5	.....	.....	.....	.....	.....
One-fourth ounce.	Aug. 17	5	Aug. 24	7	16	3	1	.....	20	3	2	.....	.....	5	1	1	.....	.....	2
		5	Aug. 31	14	7	1	.....	.....	8	2	1	.....	.....	3	2	1	.....	.....	3
		5	Sept. 11	25	5	2	.....	.....	7	2	1	.....	.....	3	2	1	1	.....	4
		5	Sept. 25	39	.....	.....	1	.....	1	.....	.....	.....	.....	.....	26	1	2	.....	29
Total	.....	99	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

It was found necessary in this work to differentiate between what were apparently normally active larvæ and those which, although slightly active, were visibly affected by the gas. The larvæ therefore were classified into dead, stupefied, and active. Whether stupefied larvæ eventually recover or die seemed to be largely a question of the duration and toxicity of the fumigation, and the degree to which the larvæ were affected. Stupefied larvæ when placed in the open air sometimes recovered and sometimes died, but the determination of the exact condition under which either took place was impossible. It was determined, however, that larvæ apparently much affected may be revived. On the other hand, when the dosage was sufficient to provide for a continuation of the fumigation much beyond the time at which the examination was made it may be assumed with safety that the stupefied larvæ eventually would have been killed.

In Table I it will be seen that a 1-ounce dose, applied July 19, showed 9 days after application a small number of larvæ stupefied. By the time of the next examination, however, 14 days after application and in the two succeeding examinations, the larvæ were all dead.

Very little can be added to these data by an extended discussion. The principal facts in regard to dosage are brought out in Table I. In the study of the table, however, it should be emphasized that the relative numbers of dead and living larvæ in the last two examinations for each dose are somewhat misleading, due to the early decomposition of many of the dead, especially the smaller ones. The 1-ounce and one-half-ounce doses were more quickly and fully effective in the July applications than in the August applications. The one-fourth-ounce dose applied August 17 was partially effective but its action was not sustained, and by the time of the last examination, 39 days after application, the dose had been dissipated so completely that young larvæ which were hatching at the time were able to enter the trees. The one-half-ounce and the 1-ounce doses both gave very complete immunity from this current infestation of newly hatched larvæ. The importance of this point will be emphasized later in connection with the time of application and the final control obtained from the use of this gas.

It was observed that the larvæ of the fungus-gnat, *Mycetobia* sp., which feed in the gum, apparently succumb to the action of the gas in about the same proportion as do the larvæ of *exitiosa*.

From the results of the experiments with p-dichlorobenzene given in Table I it will be seen that at the soil temperatures prevailing in late July and August a dose of 1 ounce per tree has a very effective larvicidal action. The vapor apparently acts rather slowly, how-

ever, and no definite statement can be made as to the exact time required for the gas to kill all the larvæ. This, of course, depends upon the concentration of the soil vapor and the condition of the insect. These points are discussed more fully in a later paragraph. Occasionally larvæ subjected to the fumigation apparently live for weeks in a comatose condition, their bodies shrinking to one-half or one-third normal size before death. There is no means of knowing whether this is due to an unequal distribution of the gas or to the greater vitality of the individual so affected. As a rule, after the application of an effective dose in late summer and early fall most of the larvæ are killed within a period of about two weeks.

Use as a Control Measure.

time of application.

The extent to which an application of p-dichlorobenzene may act as a control measure for the peach-tree borer depends greatly on the season of the year in which it is made. In the central latitudes, where most of the experimental work was done, the hatching period of the insect extends more or less over at least three months—July, August, and September. In exceptional seasons, and perhaps to some extent every season, it may be extended from one to two weeks in either direction from these limits.

It has been found that a single application of an effective dose made in the early fall gives a very fair degree of control. Apparently the ideal time would be from two to three weeks before the end of the hatching period. Applied at that time it kills all the larvæ except a few of the more perfectly protected that have already entered the tree, and provides an immunity from the attacks of those which hatch later and appear during the progress of the fumigation. Also the soil temperatures at this time are sufficient to vaporize most of the material before winter, a point discussed in a later paragraph in connection with injury. The seasonal fluctuations in the period of egg deposition prevent the determination of the time of application to any very great degree of exactness. The period for effective application, however, apparently has no arbitrary time limits. Table II gives the summarized results of about 15 experiments carried on in West Virginia, Virginia, and Maryland in 1916, 1917, and 1918.

TABLE II.—*Relative effectiveness of a single fall application of stated doses of p-dichlorobenzene. 1916–1918.*

Observation.	Application per tree.				Check untreated.
	¼ ounce.	½ ounce.	¾ ounce.	1 ounce.	
Total number of trees	10	88	272	298	224
Number of trees not infested	4	61	226	256	22
Number of trees infested	6	27	46	42	202
Total number of larvæ	25	90	98	85	1,669
Maximum number of larvæ on one tree	11	9	6	6	44
Average number of larvæ per tree for trees infested	4.1	3.3	2.1	2	8.2
Average number of larvæ per tree for total number of trees	2.5	1	.36	.28	7.4
Approximate percentage of control	70	88	95	96	0

The time of application varied from the last of August to the last of September, yet in no case was there a very decided departure from the general average of control given in the table. In some cases when application was made about the 25th of August the fumigation was apparently over a little too soon, indicated by a slight infestation of newly hatched larvæ. On the other hand, applications made the last of September, while entirely effective, had the disadvantage of incomplete evaporation. The ideal time apparently was in early September, approximately the 10th.

In 1917 about 80 trees were treated at Springfield with a 1-ounce dose each. One plat received one application on July 7; one plat two applications, the first on July 7 and the second on August 24; and one plat one application on August 25. The plat receiving one application July 7 gave a control of 45 per cent when examined on October 11. The plat receiving two applications gave a control of 96 per cent, and the plat receiving one application on August 25, 90 per cent. Table III gives the results of this treatment.

TABLE III.—*Relative effectiveness of one and two applications per season of a 1-ounce dose of p-dichlorobenzene per tree, Springfield, W. Va., 1917.*

Applications.		Dates of examination.	Number of trees—		Number of active larvæ.		Percentage of control
Number.	Date.		Treated.	Examined.	Total.	Average per tree.	
1	July 7	Oct. 11	29	20	66	3.3	45
2	July 7 and Aug. 24	Oct. 11	38	20	5	.25	96
1	Aug. 25	Oct. 16	13	13	8	.6	90
Check				28	169	6	0

The difference in control between the plat treated twice and that treated once on August 25 is too slight to be of special importance, and certainly not sufficient to warrant the double application in practice. Aside from consideration of economy two applications per

season have the added disadvantage of subjecting the tree to a double fumigation and a proportionately greater chance of injury, although no injury was observed on the trees so treated.

While very good results have been obtained from applications made all the way from the last of August to the last of September, very late application has been less satisfactory. In 1916 the 1-ounce dose was applied to 48 trees at Springfield on November 1. Examination was made the following spring on May 28, about seven months later. Large numbers of dead and decomposing larvæ were found on the trees. An unusual number, however, had escaped. Compared to adjacent untreated trees the indicated mortality was 87 per cent. A slight amount of the material was still in the soil, and from the appearance of the larvæ it was suspected that a considerable part of the fumigation had taken place in the spring. There was also more or less injury about wounds and exposed tissue. The larvæ are probably much more resistant to fumigation during the dormant period than at any other season of the year.

It has been found that with all gases the trees recover more readily from injury which occurs in early spring just at the beginning of the growing season than at any other time of the year, and other things being equal that would be the logical time to apply fumigation. Records of soil temperatures made at Springfield in 1916, however, indicate that the soil warms up rather slowly in the spring. At a depth of 6 inches the temperatures of the period from September 15 to October 15 were not attained in the spring until about May 15 to June 15. It is hardly probable that effective application could be made in the spring much before May 15. By this time a great number of the larvæ have reached a considerable degree of maturity at the expense of much injury to the tree, and while the gas would probably reach a large proportion, the depth and character of the burrows of the larger larvæ provide more or less chance for their escape.

As already stated, early fall, from two to three weeks before the end of the hatching period, proved the most effective time for application. In the latitude of Washington this is about the 10th of September. At this time larvæ that have already entered the trees are mostly small, feeding in the outer layers of bark in more or less exposed locations, while the soil temperature is sufficient to evaporate the material before winter.

For other localities both north and south of the latitude of Washington, the time of application undoubtedly can be established approximately from what is known of the insects' seasonal history in various parts of the country. In Table VI it will be seen that there was a wide variation in the dates applications were made in the same locality in 1916, 1917, and 1918. As a matter of fact, all of the appli-

cations of 1918 were made from two to three weeks later than was originally planned, and, while the results of these experiments were quite satisfactory so far as the larvicidal action was concerned, a considerable amount of the material remained about the trees at the time examinations were made. There is reason to believe that the dates originally adopted are more satisfactory. These dates are as follows:

Michigan, Ohio, Connecticut	September 1
New Jersey, West Virgina, Maryland	September 10
North Carolina and the Ozarks	September 25
Georgia and Texas	October 10

In the study of Table VI it should be remembered that the examinations were made several weeks and in some cases several months after application. Dead larvæ, of course, were largely decomposed after such a lapse of time. Hence no account was taken of anything but living larvæ. Dead skins and partly decomposed bodies were always in evidence but no attempt was made to determine the actual infestation from their numbers. The check plat by which the relative infestation was judged in all cases was made up of consecutive trees in adjoining parallel rows.

DOSAGE.

Table VI sets forth with sufficient clearness the essential features of dosage efficiency. It will be seen that the doses applied as a single fall treatment gave results which agree very closely with their previously determined larvicidal value given in Table I. The trees treated in these experiments varied in age from 6 to 15 years and in size at the butts from one to several inches in diameter. It might be argued that the collar girth of the trees would be a better index to the dosage required than their age. There are certain facts, however, which make this undesirable. First, as will be shown later, injury is more dependent upon the age of the tree and the development of protective tissue than upon its size. Second, there has been a wide latitude in the size of trees treated successfully by a given dose. Under field conditions there is at all times a heavy surface and lateral loss of gas. It seems probable for that reason that there is a certain area of gas diffusion necessary before the vapor in the center of this area attains toxic concentration. There are, of course, limits in both directions in the application of this statement, very large trees undoubtedly requiring larger doses than small ones. In practice, however, the latitude in collar girth of trees which a given dose will treat successfully has been enough to cover the usual variation in trees between the ages of 6 and 15 years.

It will be seen in Table VI that the one-fourth-ounce dose gave only partial control. Although only one experiment included the application of this amount, the results agreed fairly well with its

previously determined larvicidal value. The one-half-ounce dose in many instances gave as perfect control as the next two larger doses, and in some cases better. On the whole, however, the results from the application of this dose are not quite so uniform and the general average is slightly less. As will be seen from the table, there is not a great difference in the control obtained from either the one-half-ounce, the three-fourths-ounce, or the 1-ounce doses. Apparently there is considerable latitude in the dosage required, within these limits, but it does not seem likely that much less than one-half-ounce doses would give consistent control. On the other hand, there does not seem to be much point in using doses larger than 1 ounce.

Other experiments were carried on in which very much larger doses than those shown in Table VI were used, but in none of these was there an advantage in the control obtained sufficient to offset the probability of injury from the greatly prolonged fumigation. Table IV gives the results of one such experiment, made at Springfield in 1916.

TABLE IV.—*Effect of stated doses of para-dichlorobenzene on 8-year-old peach trees, Springfield, W. Va., 1916.*

Number of trees.	Dose per tree.	Date of—		Interval in days from application to examination.	Number of active larvæ.		Injury.
		Application.	Examination.		Total.	Per tree.	
5	½ ounce	June 24	Oct. 14	112	29	5.8	None.
5	do	do	Oct. 27	125	12	2.4	None.
5	do	do	Oct. 28	126	3	.6	None.
5	do	Aug. 22	do	67			None.
5	1 ounce	June 24	Oct. 14	112	9	1.8	None.
5	do	do	Oct. 18	116	25	5.0	None.
5	do	do	Oct. 27	125	15	3.0	None.
5	do	do	do	125	6	1.2	None.
5	do	Aug. 22	Oct. 28	67			None.
5	2 ounces	June 24	Oct. 14	112			None (1 tree moderate).
5	do	do	Oct. 18	116	3	.6	None.
5	do	do	Oct. 28	126	4	.8	None.
5	do	do	Oct. 27	125			None.
5	do	Aug. 22	Oct. 28	67			None.
5	3 ounces	June 24	Oct. 14	112			None.
5	do	do	Oct. 27	125			None.
5	do	do	Oct. 28	126			None.
5	do	do	Oct. 27	125			None.
5	do	Aug. 22	Oct. 28	67			None.
5	4 ounces	June 24	Oct. 14	112			None (1 tree severe).
5	do	do	Oct. 27	125			None.
5	do	do	Oct. 28	126			None.
5	do	do	do	126			None.
5	do	Aug. 22	do	67			None.
2	6 ounces	do	do	67			None (1 tree traces).
2	8 ounces	do	do	67			Traces.
2	10 ounces	do	do	67			None (1 tree traces).

Total number of trees treated, 126.

A total of 126 eight-year-old trees were treated with various doses, ranging from one-half ounce to 10 ounces per tree. Part of the applications were made June 24 and part August 22. The examination was made in October. Of the entire 126 trees, 56 which received

3 ounces each and over were entirely free from larvæ; 20 trees receiving 2 ounces each on June 24 contained 7 larvæ, an average infestation of 0.35 per tree; 5 trees receiving 2 ounces each August 22 contained none; 20 trees receiving 1 ounce each on June 24 contained 55 larvæ, an average infestation of 2.7 per tree; 5 trees receiving 1 ounce each on August 22 contained none; 15 trees receiving one-half ounce each on June 24 contained 54 larvæ, or an average of 3.6 per tree; and 5 trees receiving the same dose on August 22 contained none. It is especially significant that the single application of a moderate dose the last of August gave as good control, in the end, as a June application of a much larger dose.

INFLUENCE OF SOIL TYPE.

So far as the present experiments go the influence of soil type on the effectiveness of the application of p-dichlorobenzene has imposed no limitations on its use. While the fumigation probably may be expected to prove somewhat less effective in some cases where extreme variation in soil types exists, it has been used so far with almost uniform results on a variety of soils. In this respect it possesses a distinct advantage over gases like carbon disulphid and carbon tetrachlorid, which volatilize so rapidly at ordinary temperature that the fumigation is over in a few days. The relative diffusion of gases at various times in a given soil type depends mainly on the variation of moisture content. A highly volatile gas for that reason possesses a distinct disadvantage, since it is governed entirely by the particular condition of the soil, with respect to moisture, which exists within a period of a few days. This condition may be one of extreme dryness or extreme wetness, or, in case of a heavy rain, both conditions may be present. It is apparent, therefore, that a material of low volatility at ordinary soil temperature, which gives a comparatively mild fumigation, and requires a long period for its action, not only takes advantage of the equalization of soil moisture conditions that usually occurs over a period of several weeks, but at the same time is less seriously affected by sudden violent fluctuations that may occur at any time.

Table VI gives the results obtained on several types of soil varying in character from sandy loam to comparatively heavy clay loam. At Pinto, Md., where the soil type is a variation of the Frankstown series, known as stony silt loam, locally called chert land, the greatest difficulty is encountered in its use. When cultivation of this soil is followed for some time, it appears often almost entirely free of fine material on the surface. Below the immediate surface, however, it is usually well filled with fine soil. The chief difficulty in making application to this type of soil was due to the lack of fine material. As will be seen in Table VI the results were quite

satisfactory on this type of soil, and the mechanical difficulty involved in its application would probably be no greater than in "worming."

For the types of soil upon which experiments have been made no consistent variation in control has so far been observed. The comparative mildness of the fumigation and the long period over which it acts apparently tend to neutralize the influence of soil type.

Injury to Trees.

The margin of safety in the use of p-dichlorobenzene against the peach-tree borer apparently depends entirely upon the relative extent to which the insect and the tissues of its host are exposed to the action of the gas. In the main this relation varies in proportion to the age of the tree and the development of its protective tissues. It has been found impossible to fumigate young trees with safety. On the other hand trees beyond a certain age have shown so far no ill effects from a fumigation of several times the duration necessary to kill the insect.

In the course of three years' work many hundreds of observations have been made on the collars of trees treated with a great variety of doses on a number of different soils. In some cases blocks of trees have been treated for two successive seasons and in one case for three years. In part, the observations have been made in connection with "worming" data, and in part they are the results of separate dosage experiments.

NURSERY TREES.

In 1916, 57 nursery trees were treated in a nursery at Hagerstown, Md. The trees were Belle of Georgia buds of the previous fall. The soil was a stiff clay loam. The dosage was distributed over the 57 trees as follows: 10 received one-fourth ounce each; 10 one-half ounce; 10 three-fourths of an ounce; 10, 1 ounce; 5, 2 ounces; 5, 3 ounces; 2, 4 ounces; 2, 5 ounces; and 3 individual trees received 6, 8, and 10 ounces, respectively. The application was made on September 6. On October 21 the trees were dug and examined. In this interval of 45 days all of the trees had been injured severely by the gas. No distinction could be made between the various doses in the extent of the injury, which was as severe on trees receiving one-fourth ounce as on those receiving more. The injury was localized on the collar and larger roots lying within 6 to 8 inches of the material. The greatest amount of tissue killed was in the vicinity of wounds, but even on uninjured stems where the epidermis was not ruptured the surface was peppered with tiny lesions extending into the cambium.

TWO-YEAR ORCHARD TREES.

The effect upon two-year orchard trees proved less serious, although much too great to make their fumigation practicable. On August 18, 1916, 20 Belle of Georgia trees were treated in an orchard at Vienna, Va. These trees were in their second season from planting and were consequently two years older than the nursery trees. The soil was exceptionally stiff clay loam. With one or two exceptions these trees were vigorous and normal. Table V gives the date of application, dosage, and the results of later observations on the effects of the fumigation.

TABLE V.—*Effect of stated doses of para-dichlorobenzene on 2-year-old Belle of Georgia peach trees, Vienna, Va., 1916–17.*

Tree Nos.	Condition of trees before treatment.	Dose.	Date of application.	Condition of trees on specified dates of examination.	
				Mar. 14, 1917.	July 24, 1917.
			1916.		
1	Normal..	¼ ounce...	Aug. 18	Moderate injury, not serious....	Fully recovered, normal growth.
2	...do.....	...do.....	...do.....	Slight injury, not serious.....	Do.
1	...do.....	½ ounce..	...do.....	.....do.....	Do.
2	Weak...	...do.....	...do.....	Dead.....	
1	...do.....	¾ ounce..	...do.....	Slight injury, not serious.....	Do.
2	Normal..	...do.....	...do....	Severe injury, girdled.....	Dead.
1	...do.....	1 ounce..	...do.....	Severe injury, three-quarters girdled.	Partly recovered, normal growth.
2	Weak...	...do.....	...do.....	Slight injury, not serious.....	Fully recovered, normal growth.
1	Normal..	2 ounces .	...do.....	.....do.....	Do.
2	...do.....	...do.....	...do....	Severe injury, girdled.....	Dead.
1	...do.....	3 ounces.	...do.....	Slight injury, not serious.....	Fully recovered, normal growth.
2	...do.....	...do.....	...do.....	Severe injury, three-quarters girdled.	Partly recovered, normal growth.
1	...do.....	4 ounces..	do.....	Severe injury, girdled.....	Dead.
2	...do.....	...do.....	...do....	Traces injury, not serious.....	Fully recovered, normal growth.
1	...do.....	5 ounces..	...do.....	Severe injury, serious.....	Partly recovered, normal growth.
2	...do.....	...do.....	...do.....	Traces injury, not serious.....	Fully recovered, normal growth.
1	...do.....	6 ounces..	...do.....	Slight injury, not serious.....	Subnormal, stunted.
2	...do.....	...do.....	...do.....	Traces injury, not serious.....	Fully recovered, normal growth.
1	...do.....	8 ounces..	...do....	Moderate injury, not serious....	Do.
1	...do.....	10 ounces.	...do.....	Severe injury.....	Subnormal, stunted.

It will be noted by reference to Table V that for all doses up to and including 5 ounces the injury to one tree is recorded as "slight" or less, while the other was injured more severely. Table V also shows that on July 24, 1917, when they were again examined, all injured slightly had recovered and made a normal growth. For each dose, therefore, up to and including 5 ounces, one tree entirely recovered and made a normal growth the season following fumigation. Apparently for the period over which the experiment was allowed to run, the smaller doses were sufficient to furnish a vapor of maximum toxicity. Had the experiment been allowed to run longer, it is probable that a greater graduation in the toxicity of the various doses would have been observed, as the larger doses had by no means completely volatilized at the time the examination was made. As in

the case of the nursery trees, the greatest injury occurred about wounds. There was noticeably less injury where the protective tissue was not ruptured than on the uninjured stems, although in many cases the gas had killed large patches and partly girdled uninjured collars.

FOUR-YEAR ORCHARD TREES.

Four-year orchard trees showed a still greater resistance to the effects of the gas. On September 9, 1916, 28 four-year Champion trees were treated in an orchard at Conway, Md., with doses as follows: Nine received one-half ounce each, 9 three-fourths of an ounce, and 10 one ounce. Five trees of each plat were examined on November 28, 1916, and the remainder on April 2, 1917. Of the entire 28 trees, 17 showed no injury at all. Of the 9 trees which had received the one-half ounce dose 7 showed no injury, while 2 were injured, 1 moderately and 1 severely. On the three-fourths-ounce plat 5 of the 9 trees showed no injury, 4 were injured, 2 severely, 1 moderately, and 1 only a trace. On the 1-ounce plat 5 of the 10 trees were uninjured; of the remaining 5, 3 showed only a trace of injury, 1 a slight injury, and 1 was entirely girdled. Of the entire lot of 28 trees only 1 was killed outright. While one or two others were partly girdled, the one last mentioned was the only tree upon which the effects of the fumigation were ever visible above ground. As usual the injury occurred more or less irrespective of dosage, its severity varying with the condition of the tree with respect to insect wounds, etc. While it was apparent that four-year trees could not be fumigated without more or less injury on lacerated stems, there was a decided diminution in its severity on trees of this age compared to those younger.

The extent to which the epidermal and cork layers of the bark are responsible for the protection of the tree was illustrated by an experiment at Springfield in 1916. A block of eight 10-year-old trees was treated with 1, 2, 3, and 4 ounce doses on July 20, two trees receiving each dose. On August 26 they were examined and no trace of injury found. However, in making the examination the trees of the 2, 3, and 4 ounce plats were considerably scarified, the outer layer of the bark being largely pared and scraped away. These trees were retreated with the same dose August 26, and examined again on October 28. On the 1-ounce plat where the collars were not scarified no injury had developed. On the other plats all the trees were injured severely, and in two cases completely girdled. On the other hand, trees of the same age in adjoining rows withstood during the same period continuous fumigation for 125 days without injury.

TREES SIX YEARS AND OVER.

A single early fall application of a moderate dose of p-dichlorobenzene has caused no injury on trees six years and over. Doses have been applied to trees of this age varying from 1 ounce to several ounces per tree. Where moderate doses of three-fourths of an ounce or 1 ounce per tree have been applied once in early fall no injury of any importance has ever been observed. Hundred of trees have been fumigated in this way, and in some cases blocks of trees have received the same doses for two and three years. While there can be no doubt that trees of any age could be killed if the fumigation was prolonged sufficiently, there is every indication that the time required would be many times that necessary to kill the borer. Occasionally in the vicinity of wounds a slight amount of tissue is killed even in fumigation with ordinary doses, but on the older trees this has been so slight and superficial in character that it may be disregarded.

Table IV gives the results of prolonged fumigation on eight-year-old trees at Springfield in 1916. As will be seen from the data there presented very little injury of importance was found on trees treated with doses giving a continuous fumigation from June 24 to the last of October. Of the entire 126 trees treated with doses ranging from one-half ounce to 4 ounces each, only two developed serious injury and in both cases the trees had been seriously injured by both borers and crown gall. Apparently the gas has considerable effect upon the spongy galls which accompany this disease. Doses of 2 ounces and over gave off a very pronounced odor when the earth was opened, and the fumigation had probably been maintained at a toxic concentration throughout most of the period from June to October. While from the standpoint of control a fumigation of so great duration is not necessary or desirable, it is interesting that all these larger doses gave almost complete immunity from the insect throughout the season.

The greatest amount of injury ever observed on older trees resulted from an application made at Springfield on November 1, 1916. (See Table VI.)

TABLE VI.—*General summary of results obtained by one fall application of para-dichlorobenzene per season, 1916–1918.*

Date of application.	Locality.	Number of seasons applied successively.	Soil type.	Treatment and results.																						Remarks.
				¼ ounce.				½ ounce.				¾ ounce.				1 ounce.				1½ ounces.				Check untreated.			
				Number.				Number.				Number.				Number.				Number.				Number.			
				Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	
1916.																										
Aug. 26	Springfield, W. Va.	1	Silt loam	10	25	2.5	69.9	10	16	1.6	80.8	10	3	0.3	96.4	11	2	0.18	97.8					10	83	8.3	9 to 10 year old trees.[1]
Sept. 9	Conway, Md	1	Sandy loam					9	1	.11	98	9	0	0	100	10	0	0	100					10	55	5.5	4-year-old trees.[2]
Nov. 1	Springfield, W. Va.	1	Silt loam													15	16	1.06	87.2					10	83	8.3	9 to 10 year old trees.[3]
1917.																										
Aug. 24	do	2	do									14	10	.72	86.9	25	20	.8	85.5					18	99	5.5	10 to 11 year old trees.[1]
Aug. 28	do	1	do					15	28	1.9	85.8	14	19	1.35	89.9	15	9	.6	95.6					10	134	13.4	6-year-old trees.[1]
Sept. 19	do	1	do					12	0	0	100	12	1	.08	99.4	12	1	.08	99.4					10	134	13.4	6-year-old trees.[1]
Sept. 9	Pinto, Md	1	Stony silt loam									25	13	.52	94.2	25	15	.6	93.4					10	91	9.1	10 to 12 year old trees.[1]
Sept. 7	Three Churches, W. Va.	1	Fine sandy loam									20	0	0	100	20	4	.2	97.4					10	77	7.7	6-year-old trees.[1]
Sept. 11	Hancock, Md	1	do									25	8	.32	96.4	25	6	.24	97.3					20	176	8.8	6 to 8 year old trees.[1]
1918.																										
Sept. 14	Winchester, Va.	1	Clay loam					21	43	2.0	78.9	23	24	1.0	89.5	23	7	.3	96.8					21	199	9.5	6-year-old trees.[1]
Sept. 24	Springfield, W. Va.	3	Silt loam									25	3	.12	94.6	20	1	.05	97.7					20	44	2.2	11 to 12 year old trees.[1]
Sept. 27	do	2	do					21	2	.09	98.2	21	1	.05	99	23	0	0	100					20	98	4.9	7-year-old trees.[1]
Sept. 25	Pinto, Md	2	Stony silt loam									25	11	.44	96	25	3	.12	98.9					15	167	11.1	11 to 12 year old trees.[1]
Sept. 26	Three Churches, W. Va.	2	Fine sandy loam									25	2	.08	98.6	25	2	.08	98.6					20	112	5.6	7-year-old trees.[1]
Sept. 30	Hancock, Md	2	do									24	3	.12	97.9	24	0	0	100					20	117	5.8	7-year-old trees.[1]
Sept. 11	Vermilion, Ohio	1	Light clay loam					20	7	.35	96.1	23	25	1.08	88	25	17	.68	92.5					25	225	9	8-year-old trees.[1]
Sept. 15	Sandusky, Ohio	1	Clay loam					25	3	.12	97.5	25	4	.16	96.7	25	6	.24	95					25	121	4.8	7-year-old trees.[1]
Sept. 30	Wakefield, Ohio	1	Light clay loam					25	11	.44	93.7	25	23	.92	86.9	25	36	1.4	80					25	175	7	9-year-old trees.[1]
Oct. 12	Springdale, Ark	1	Gravelly loam													25	6	.24	94.3					25	105	4.2	15-year-old trees.[1]
Oct. 22	Fort Valley, Ga	1	Fine sandy loam					18	2	.11	97.5	19	6	.31	92.8	21	4	.19	95.6	20	1	0.05	98.8	16	69	4.3	15-year-old trees.[1]
Do	do	1	do					18	2	.11	96.2	17	2	.12	95.9	20	5	.25	91.4					18	52	2.9	6-year-old trees.[1]
	Total			10	25	2.5	69.9	194	115	.59	91.7	381	158	.41	94.1	439	160	.36	94.7	20	1	.05	98.8	358	2,416	6.77	

[1] No injury. [2] Moderate injury. [3] Slight injury.

The trees treated were about 10 years of age and had suffered heavily from borer attacks. They received 1 ounce each. On May 28, 1917, 15 were examined. Nine showed no injury at all, 5 showed traces, and 2 what was classified as slight injury. So far as the final effect on the trees was concerned none of this injury was of importance. It was more than hitherto had been observed for this dose, however, and while the reason is not entirely apparent it is felt that it is best to make the application sufficiently early in the fall to allow for complete evaporation before winter. This fact, coupled with its less effective action, should be sufficient reason for avoiding late application. When the application is made in the central latitude as late as September 15, it probably would be wise to uncover the trees after five or six weeks, and either allow them to stand open for a time or refill with fresh earth. In fact, at the present stage of our knowledge of the problem the writer is inclined to feel that this might be a wise precaution to follow in every case.

The varieties treated have included many of the leading commercial sorts as well as a large number of unknown seedlings. So far there has been nothing to indicate that one variety of peach is more susceptible to the effects of the gas than another.

A summary of the results obtained by one fall application of paradichlorobenzene is given in Table VI.

RELATION OF INJURY TO SOIL TYPE.

No special relation between injury and type of soil has been discovered in the use of p-dichlorobenzene. Very porous soils probably give a somewhat less concentrated vapor than very retentive soils, but in practice the effect of soil type has not seemed important, although the soils on which experiments were carried on have varied from light sandy loams to heavy clay loams.

INJURY TO APPLE.

In August, 1916, an application of p-dichlorobenzene was made to twelve 3-year-old apple trees at Springfield, W. Va. These trees were treated with doses varying from 1 ounce to one-fourth of an ounce each. All were quite well infested with *S. candida*. The application was made on August 23 and the examination on September 1–2. Practically all the smaller larvæ of the borer had been killed. The more mature specimens working in deeper burrows were still living, although several were affected noticeably by the gas. The trees were severely injured, however. Apparently, the action of the gas on the insect and the tree was almost simultaneous. Several of these trees were so severely injured that they died the following season. On another occasion an 8-year-old apple tree not infested with borers or injured in any way was treated with an ounce of p-dichlorobenzene.

When examined, about one month later, it was found to be two-thirds girdled by the fumigation. While these observations are very limited they indicate a wide difference in susceptibility of apple and peach. This difference apparently is due mostly to the difference in the thickness of the bark and its layers of protective tissue, which exists between the two.

Discussion.

The experience so far obtained indicates that there are pronounced possibilities in the application of poison gases to the control of the peach-tree borer. At present p-dichlorobenzene remains the only material of decided value. Despite the fact that for three seasons it has given uniformly good results, however, it is not the purpose of this paper to encourage its use except in an experimental way. The control obtained has been by no means 100 per cent efficient, and it is doubtful if such a degree of control could be secured safely by any artificial means. Certainly it is not obtained in practice by the ordinary "worming." Unfortunately the use of this gas is restricted to trees of somewhat advanced age, but this limitation might apply as well to the application of other fumigants for the control of this insect.

The question of the volatility of p-dichlorobenzene was submitted to the Bureau of Chemistry.[1] It was found that the vapor pressure, while very low at ordinary temperature, is, roughly, about ten times as great at 100° F. as at 50° F. In the soil, however, the relation of vapor pressure and temperature to the rate of volatilization is greatly modified by such factors as barometric pressure, humidity, circulation of air, surface exposure, etc. Although there is undoubtedly a considerable variation in the rate of volatilization within the seasonal range of soil temperatures, it has not seriously interfered with the effectiveness of the gas in the field tests so far made. Soil temperature records taken throughout the season of 1916 at Springfield, W. Va., showed a variation at a depth of 6 inches from about 50° to 55° F. in April and October to 75° and 80° F. in July and August.

The vapor of p-dichlorobenzene has a very decided repellent effect upon the ovipositing moths. On several occasions females were followed through treated blocks of trees and observed to visit tree after tree, hovering about the base for a short time or alighting for an instant without depositing a single egg.

The effective range of the gas is rather local, being confined to the area reached in practice by "worming." On the bole of the tree at a depth of from 8 to 12 inches and on lateral roots at less than that depth, but more than 6 to 8 inches from the trunk, larvæ usually are not affected.

---

[1] Correspondence and notes of the Bureau of Entomology.

The writer is indebted to a number of observers for cooperation in experiments made in various parts of the country during the season of 1918. In Ohio the treatments and examinations at Sandusky and Vermilion were made by Mr. G. A. Runner, in charge of the laboratory of the Bureau of Entomology at Sandusky, in cooperation with Mr. H. J. Speaker, of the bureau of horticulture, Ohio Department of Agriculture. The work in southern Ohio at Wakefield was conducted by Mr. Speaker. At Springdale, Ark., the observations were made by Mr. A. J. Ackerman, of the Bureau of Entomology, and Mr. F. L. Pierce, of the Bureau of Plant Industry. At Fort Valley, Ga., the work was carried out by Mr. J. J. Culver, of the Bureau of Entomology, and the writer. The writer is also especially indebted to Mr. B. R. Leach, in charge of the bureau laboratory at Winchester, Va., for many valuable suggestions and for cooperation and assistance in the experiments in Virginia, West Virginia, and Maryland.

SUMMARY.

(1) It has been found impossible to standardize the use of carbon disulphid and carbon tetrachlorid as treatments for the peach borer. The great volatility of these substances at ordinary temperatures renders them too sensitive to varying conditions of soil porosity.

(2) Sodium cyanid on account of its solubility was too susceptible to the effects of variation in soil moisture and soil type, and proved to be injurious to trees.

(3) Naphthalene on account of its low volatility within the seasonal range of soil temperatures was only a partially effective larvicide for a very short period in midsummer.

(4) P-dichlorobenzene has proved quite effective over a wide range of varying conditions imposed by field practice, with a considerable margin of safety for trees six years and over.

In making the application the surface crust about the collar of the tree is broken. Excessive amounts of gummy exudations at the surface are removed. The lower levels of soil are disturbed as little as possible, and the required dose is distributed evenly about the trunk in a band 1 to 2 inches in width. (See Plate I, A.) Two or three shovels of earth are then placed over the material, and compacted with the back of the shovel, being mounded slightly to cover surface galleries (Plate I, B).

In the latitude of Washington and northern Virginia about September 10 has been found to be the most satisfactory time of application. Based on the insect's seasonal history, the theoretical time of application in the North generally would be about September 1; in the Ozarks, September 25; and in Georgia and the cotton belt, October 10.

For 6 to 15 year old trees of average size, doses of 1 ounce and of three-fourths of an ounce per tree have been found effective in destroying the borers without injury to the trees. For very large trees of advanced age, a somewhat increased dose may be desirable.

As an added precaution against injury the base of the trees should be uncovered 4 to 6 weeks after application, allowed to remain open for a few days, and recovered. This precaution is especially necessary if the application has been made very late.

The use of p-dichlorobenzene in this way has been found to reduce the infestation on the average from 6.77 to 0.41–0.36 larvæ per tree, approximately a 94 per cent control.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1919

NATIONAL AGRICULTURAL LIBRARY
1022415152